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COMMITTEE PRINT

# A REVIEW OF THE ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION'S NATIONAL ENERGY PLAN

PRINTED AT THE REQUEST OF

FRANK CHURCH, *Chairman*

SUBCOMMITTEE ON ENERGY RESEARCH AND WATER RESOURCES

OF THE

COMMITTEE ON INTERIOR AND INSULAR AFFAIRS

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## MEMORANDUM OF THE SUBCOMMITTEE CHAIRMAN

*To Members of the Senate Committee on Interior and Insular Affairs:*

In July and October of 1976, the Senate Committee on Interior and Insular Affairs, Subcommittee on Energy Research and Water Resources, held hearings on the national energy plan of the Energy Research and Development Administration. Senator Bumpers chaired these hearings at my request, as part of our oversight duties in relation to ERDA. The importance of a long-range plan for energy research and development was recognized in the ERDA enabling legislation, where an annually-updated plan was stipulated. In the Subcommittee's judgment, several portions of the plan need improvement and ERDA should make the necessary revisions to future versions of the plan so that Congress will be better able to make decisions regarding the funding of various energy research, development and demonstration programs in the years ahead. This report identifies some of the more important items needing ERDA's attention, and the Subcommittee recommends that these items be addressed in the forthcoming plan.

The Subcommittee is deeply indebted to Dr. Christopher L. Coccio for the work he did in the preparation of this document, and also for the assistance he has given to the Members to aid in their understanding of ERDA's long-range energy plan. Dr. Coccio's temporary assignment to the Subcommittee as a Congressional Fellow greatly assisted our work in the review of ERDA's program.

FRANK CHURCH, *Chairman,*
*Subcommittee on Energy Research*
*and Water Resources.*

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## A REVIEW OF THE ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION'S NATIONAL ENERGY PLAN

### I. Introduction

The Committee on Interior and Insular Affairs has responsibility for the oversight of activities of the Energy Research and Development Administration. The ERDA has been given a legislated responsibility to provide the Congress with an annually updated plan for achieving the purposes of the enabling legislation (Public Law 93–577). Briefly, the agency was required to formulate a broad-based energy technology research, development and demonstration (R, D and D) plan which assigned program elements to three time frames: short-term (up to early 1980's); mid-term (to 2000); and long-term (beyond 2000).

ERDA responded in 1975 with its first plan entitled "A National Plan for Energy Research, Development and Demonstration" (ERDA–48). Because of omissions or lack of emphases, the plan elicited significant, constructive criticism from various groups, such as the Office of Technology Assessment. The Committee, recognizing the tremendous problems that any new agency must address during its first year, delayed consideration of the proposed R, D and D plan until an updated and revised version of the plan was submitted in early 1976. This document is entitled, "A National Plan for Energy Research, Development and Demonstration: Creating Energy Choices for the Future" (ERDA 76–1). The Committee reviewed the plan and criticisms made by various interested parties and identified a number of issues that appeared to invite further discussion and deliberation.

Public hearings were held by the subcommittee in July and October of 1976, where these questions and issues about the plan were raised. Dr. Robert C. Seamans, Jr., Administrator of ERDA, and Mr. Roger LeGassie, Assistant Administrator for Planning, presented ERDA's view of the plan and planning process. The Office of Technology Assessment, the Council on Environmental Quality, the Congressional Budget Office, and other witnesses then had an opportunity to assess the plan in subsequent hearings. Several letters of inquiry were also sent to ERDA requesting responses to specific issues that were raised during the hearings. Finally, Dr. Seamans and Mr. LeGassie returned before the Subcommittee a second time to address various issues and questions raised in prior testimony.

This document presents background information on the national energy plan, the issues deemed most important by the subcommittee relative to this plan, and the views of the subcommittee and its recommendations to ERDA regarding the improvement of future versions of the national energy plan.

## II. A Summary of ERDA's National Energy Plan

In ERDA's view, the private sector must play the paramount role in development and commercialization of near-term energy technology. The Federal government's role will be supplementary, doing only that which private industry will not or cannot do, such as setting policy, managing Federal resources, and ensuring public and environmental welfare. ERDA's role will be to create a national energy plan, identify R, D and D aspects, and support them as necessary. Actual funding for programs is based on consideration of (1) the stage of technology development, (2) R and D versus other Federal approaches, and (3) the ability of the private sector to accomplish the R and D.

The plan identifies five overall national energy goals as follows:

a. maintain the security and policy independence of the nation;

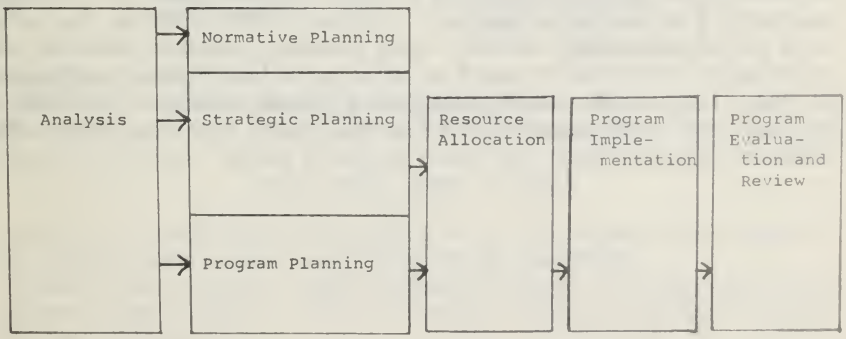
b. maintain a strong and healthy economy;

c. provide for future needs so that future lifestyles are not limited by energy unavailability;

d. contribute to world stability; and,

e. protect and improve the nation's environmental quality.

To meet these national goals, a formalized planning process has been developed, and it is entitled the Planning, Programming, Budget, and Review System (PPBR). This system is best illustrated by the flow chart below:




The first step, analysis, is self explanatory. The next step involves three types of planning; normative, strategic, and program planning. Normative planning is defined as identifying what ought to be done to solve our energy problems. This aspect of planning identifies eight major national energy technology goals as follows (taken from ERDA 76–1):



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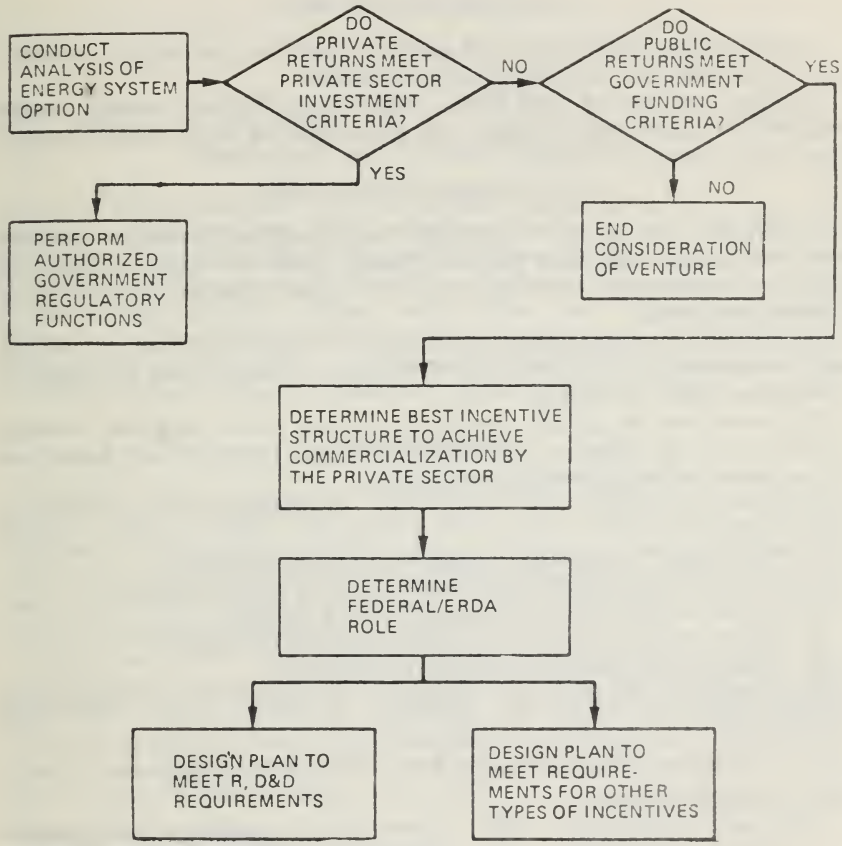
| Technology | Term of impact | Direct substitution for oil and gas | R.D. & D. status | Impact in year 2000 in quads |
|---|---|---|---|---|
| Goal I: Expand the domestic supply of economically recoverable energy producing raw materials: | | | | |
| Oil and gas—Enhanced recovery | Near | Yes | Pilot | 13.6 |
| Oil shale | Mid | Yes | Study/pilot | 7.3 |
| Geothermal | Mid | No | Lab/pilot | 3.1–5.6 |
| Goal II: Increase the use of essentially inexhaustible domestic energy resources: | | | | |
| Solar electric | Long | No | Lab | 2.1–4.2 |
| Breeder reactors | Long | No | Pilot/demo | 3.1 |
| Fusion | Long | No | Lab | |
| Goal III: Efficiently transform fuel resources into more desirable forms: | | | | |
| Coal—Direct utilization utility/industry | Near | Yes | Pilot/demo | 24.5 |
| Waste materials to energy | Near | Yes | Comm | 4.9 |
| Gaseous and liquid fuels from coal | Mid | Yes | Pilot/demo | 14.0 |
| Fuels from biomass | Long | Yes | Lab | 1.4 |
| Goal IV: Increase the efficiency and reliability of the processes used in the energy conversion and delivery systems: | | | | |
| Nuclear converter reactors | Near | No | Demo/comm | 28.0 |
| Electric conversion efficiency | Mid | No | Lab | 2.6 |
| Energy storage | Mid | No | Lab | |
| Electric power transmission and distribution | Long | No | Lab | 1.4 |
| Goal V: Transform consumption patterns to improve energy utilization: | | | | |
| Solar heat and cooling | Mid | Yes | Pilot/demo | 5.9 |
| Waste heat utilization | Mid | Yes | Study/demo | 4.9 |
| Electric transport | Long | Yes | Study/lab | 1.3 |
| Hydrogen in energy systems | Long | Yes | Study | |
| Goal VI: Increase end-use efficiency: | | | | |
| Transportation efficiency | Near | Yes | Study/lab | 9.0 |
| Industrial energy efficiency | Near | Yes | Study/comm | 8.0 |
| Conservation in buildings and consumer products | Near | Yes | Study/comm | 7.1 |
| Goal VII: Protect and enhance the general health, safety, welfare, and environment related to energy. | | | | |
| Goal VIII: Perform basic and supporting research and technical services related to energy. | | | | |

Once these desirable goals have been defined, it becomes necessary to develop an effective approach to achieving the goals, i.e., strategic planning. The strategic planners determine first whether the effort in a given technology will be done privately; if not, whether the government should do it; and if so, what is the best Federal mechanism to use. If research, development, and demonstration turns out to be the best mechansim, ERDA would carry out the effort. The strategic planning logic flow chart is shown below:


CONDUCT ANALYSIS OF ENERGY SYSTEM OPTION
DO PRIVATE RETURNS MEET PRIVATE SECTOR INVESTMENT CRITERIA?
NO
DO PUBLIC RETURNS MEET GOVERNMENT FUNDING CRITERIA?
YES
YES
NO
PERFORM AUTHORIZED GOVERNMENT REGULATORY FUNCTIONS
END CONSIDERATION OF VENTURE
DETERMINE BEST INCENTIVE STRUCTURE TO ACHIEVE COMMERCIALIZATION BY THE PRIVATE SECTOR
DETERMINE FEDERAL/ERDA ROLE
DESIGN PLAN TO MEET R, D&D REQUIREMENTS
DESIGN PLAN TO MEET REQUIREMENTS FOR OTHER TYPES OF INCENTIVES

ERDA's strategic planning identifies those efforts that meet its criteria for R, D and D support, and it categorizes them in three time frames as follows:

NEAR TERM (NOW TO 1985)

Increase the efficiency of energy used in all sectors of the economy and extract more usable energy from waste materials.

Preserve and expand major domestic energy systems: coal, light water reactors, and gas and oil from new sources and by enhanced recovery techniques.

MID TERM (1985 TO 2000)

Accelerate the development of new processes for producing synthetic fuels from coal and extracting oil from shale.

Increase the use of fuel forms such as geothermal energy, solar energy for heating and cooling, and extraction of more usable energy from waste heat.

LONG TERM (BEYOND 2000)

Permit the use of the essentially inexhaustible resources: nuclear breeders; fusion; and solar electric energy from a variety of options including wind power, thermal and photovoltaic approaches, and ocean thermal gradients.

Provide the technologies to use the new sources of energy, which may be distributed as electricity, hydrogen, or other forms throughout all sectors of the economy.

The next step is actual program planning which involves setting priorities for the different technologies. These priorities are based on the answers to the following questions:

(a) How substantial will the energy contribution be for a given technology?
(b) When will the energy technology have an impact?
(c) What is the present and projected cost-benefit status?
(d) Is there a direct substitution for oil and gas?
(e) What are the environmental and health problems?
(f) What is the status of present technology?

The resulting priorities are shown in the table below (taken from ERDA 76–1):

*Proposed national ranking of R.D. & D. technology categories* [1]

| | |
|---|---|
| Highest priority demand: | |
| Near-term conservation (efficiency) technologies. | Conservation in buildings and consumer products; industrial energy efficiency; transportation efficiency; and waste materials to energy. |
| Highest priority supply: | |
| Near-term major energy systems. | Coal-direct utilization in utility/industry; nuclear-converter reactors; and oil and gas enhanced recovery. |
| New sources of liquids and gases for the midterm. | Gaseous and liquid fuels from coal; and oil shale. |
| "Inexhaustible" sources for the long term. | Breeder reactors; fusion; and solar electric. |
| Other important technologies: | |
| Underused (limited application) midterm technologies. | Geothermal; solar heating and cooling; and waste utilization. |
| Technologies supporting intensive electrification. | Electric conversion efficiency; electric power transmission and distribution; electric transport; and energy storage. |
| Technologies being explored for the long term. | Fuels from biomass; and hydrogen in energy systems. |

[1] Individual technologies are not ranked within the technology categories.

Each category would then be looked at in finer detail to determine the main problems barring implementation, the strategies for overcoming these problems, and a plan of action defining time and money needs.

## III. Issues of Concern to the Subcommittee on Energy Research and Water Resources

Since ERDA published its first national energy plan, there have been various critical analyses of its adequacy, balance, and realism. The latest plan has attempted to respond to these critiques, and there is no question that the work of the Office of Technology Assessment, the Congressional Budget Office, and others has influenced ERDA. However, in the Subcommittee's view, several major unresolved issues still exist in regard to the national energy plan which require attention on ERDA's part. These issues are treated in the following sections.

### GOALS/ISSUES

Any plan must begin with knowledge of past trends and the current status. Goals are then set for the future and various paths to these goals are described and analyzed. Assumptions must be made about the viability of these alternative paths. The final plan thus reflects both the goals which were stated and the assumptions which were made regarding the alternative paths to the goals.

In general, there is fair agreement regarding the history of our energy situation and the current status of our energy technologies. No such agreement exists, however, regarding the goals and assumptions. Thus, the Subcommittee's first attention was directed at reviewing the goals which ERDA had set for itself and three goals issues have been identified in ERDA's plan.

*Energy Self-Sufficiency*

Public Law 93–438 states in section 2(a) that:

> The Congress hereby declares that the general welfare and the common defense and security require effective action to develop, and increase the efficiency and reliability of use of, all energy sources to meet the needs of present and future generations, to increase the productivity of the national economy and strengthen its position in regard to international trade, to make the nation self-sufficient in energy, to advance the goals of restoring, protecting, and enhancing environmental quality, and to assure public health and safety.

Energy self-sufficiency is thus mentioned as one of the purposes for the creation of ERDA, and this is to be expected since our oil imports had risen to 6 million barrels per day in 1973 at the time of the oil embargo—36% of our total oil usage—and the effect of the embargo caused severe social, economic, and environmental problems. The timing and degree of energy self-sufficiency is thus expected to be a central goal of any ERDA national plan.

The national plan accepts the President's goal of 3.5 million barrels per day of imports by 1985 without discussion, and proceeds to Five National Policy goals, which are listed below:

(1) Maintain the security and policy independence of the nation.

(2) Maintain a strong and healthy economy, providing adequate opportunities and allowing fulfillment of economic aspirations (especially in the less affluent parts of the population).

(3) Provide for future needs so that future life-styles remain a matter of choice and are not limited by the unavailability of energy.

(4) Contribute to world stability through cooperative efforts in the energy sphere.

(5) Protect and improve the nation's environmental quality by assuring that the preservation of land, water and air resources is given high priority.

The advantage of the President's goal over ERDA's subsequent goals is that it is a measurable quantity. It will be possible in 1985 to decide whether or not the goal has been achieved, and it is possible to discuss its merits today. For example, considering the effect of the 1973 embargo of 6 MBPD, it is difficult to characterize the impact of 3–5 MBPD as "energy self-sufficiency". By way of contrast, ERDA's National Policy goals lack quantification. It will be difficult to decide in 1980 or 1985 how successful the effort has been, since these goals are left in general terms.

*Recommendation.*—ERDA's central goal should be to promote energy self-sufficiency. This central goal should be stated as target United States petroleum product consumption levels at periodic future dates. Reduction or increase in projected petroleum product consumption should be justified in terms of assumptions, desirability, and realism.

*Energy Supply versus Energy Demand*

A second key element in the plan must be the division of effort between increasing energy supplies and reducing demand for energy. For example, the Ford Foundation study concludes that zero energy supply growth is possible after 1985 (*A Time to Choose*, p. 326). However, most current studies by ERDA and others conclude that strong conservation efforts can reduce, but not eliminate the need for energy supply growth.

ERDA, in its current National plan, raises conservation to the level of highest priority in the near term (now until 1985). While this ranking is praiseworthy, the stated Energy technology goal itself—increasing end use efficiency—is not quantified in the plan. If ERDA were to state the energy conservation target to be achieved as a result of its programs in estimated MBPD of oil saved for each year from now until year 2000, then Congress, ERDA, and the general public could judge the adequacy of national conservation efforts.

*Recommendation.*—ERDA's subsequent national plans should state a target of reduction of energy demand in MBPD of oil to be saved by its programs. This figure, on an annual or periodic basis, would provide a measurement for evaluating the effectivness of ERDA's conservation program.

*Energy Technology Versus Energy Systems*

The national energy effort as defined in the establishing legislation is to be similar in scope to Manhattan and Apollo projects. However,

it is recognized that those efforts delivered a product to a specific government customer with a specific technology need. In contrast, the energy technology effort will ultimately be successful only if industry markets the results and the general public accepts and utilizes the products.

Nuclear power from breeder reactors, for example, will not be of use unless the public accepts the risks involved—the minimization of these risks involves a much broader program than technical R, D & D, including protection against sabotage, terrorism, and effective international controls on waste materials. Synthetic fuels will not be used until social, economic issues of development in rural areas have been addressed, along with the environmental impacts associated with surface mining, oil shale waste disposal, and air and water quality. Also, the final product must be produced at a price competitive with the cost of alternative fuels at the time of commercial production. Successful energy conservation programs will certainly require much more than technical R, D and D efforts. Local building codes, capital availability on attractive terms, and consumer education will be important to the actual implementation of the broad spectrum of necessary energy conservation methods.

It is clear that the ERDA enabling legislation recognized these wider energy systems problems, and it is also evident that ERDA recognizes that it cannot merely develop technical options. However, many of the needed systems tasks seem beyond ERDA's jurisdiction. One useful purpose which the annually updated plan could serve would be to identify non-technological barriers that may be beyond ERDA's control, yet which require action. Congress could then respond to these identified needs in whatever way it judges appropriate.

*Recommendation.*—ERDA's national plan should identify impediments to the energy independence goal which require action, but which may be beyond ERDA's responsibility or mandate.

### FUNDING LEVEL ASSUMPTION ISSUE

As previously stated, assumptions are necessary in developing a plan to reach future goals, since there are numerous possible paths to the goal. Significantly different national energy plans will result if the nation allocates $20 billion over 10 years for energy R, D and D, than if it allocates $40 billion over 5 years. The level and timing of funding is a significant factor in determining when and if the goal of energy independence is reached, as well as how it is reached (see for example, the Congressional Budget Office report, "*Energy Research:* Alternative Strategies for Development of New Energy Technologies and their Implication for the Federal Budget").

Since ERDA's funding will be decided annually by the Congress, it is not possible for ERDA to know its funding level over the life of its plan. ERDA, however, must make assumptions regarding the levels of funding it expects to receive, in order to postulate a national energy plan. Such assumptions implicitly must be a part of the development of any long-range plan.

Were ERDA to explicitly specify the funding level and profile it is assuming in conjunction with its proposed plan, Congress could then determine whether the assumption, in light of expected achievement, is realistic or whether it wants another alternative plan that reflects

a greater or lesser spending pattern, or entails a different spending schedule.

In addition, because the private sector is expected to contribute funds toward development of energy technologies, it is important that the Congress have some idea as to the amount of commitment which ERDA estimates will be made by that sector. Only by knowing what private industry is doing can Congress be assured that efforts by the Federal Government are not merely a substitution for efforts previously done by private industry.

At present, ERDA has submitted a 5 year spending projection in conjunction with the 1977 budget request. This projection shows the expenditure level for energy R, D and D outlays rising from $2.7 billion in 1977 to $3.1 billion in 1979, then tapering off to $2.9 in 1981. The total projected outlays for the 5 year period is about $15 billion. The Congressional Budget Office has analyzed the ERDA budget, and estimates 10 year expenditures at $41 billion. This budget is termed the "Base Program Completion", since it only allows for completion of present programs. CBO identifies other possible programs, one termed "Full Funding" which reaches $64 billion in 10 years. If ERDA's funding level assumption were clearly stated, Congress would have a significant means by which to judge the desirability of this assumption against other alternatives that are available.

*Recommendation.*—From the standpoint of effective Congressional oversight and to provide the general public with a view of the level of commitment necessary to achieve the objectives for development of energy producing and conserving alternatives, ERDA's national plan should forecast total expected spending levels on an annual basis over at least a 10 year period by both public and private sources. Such a forecast, based on ERDA's best estimate of the likely technology mix it will be funding, is more likely to result in Congressional awareness and support of budgetary needs.

### COST-BENEFIT INFORMATION

One of the most significant issues to arise from the hearings involved Congress's need to know the estimated costs and energy benefits of the various programs being funded by ERDA. As Senator Bumpers expressed at one point during the hearings:

> . . . almost every witness that has appeared here has concluded . . . that . . . ERDA ought to provide the Congress with various cost effective options.
>
> . . . Congress has to have that kind of information from ERDA to make a sensible decision . . . In other words, we have to have something to compare their recommendations against.

This sentiment led to a letter that was sent to ERDA by Senator Jackson requesting clearly defined targets and costs associated with each of ERDA's Energy Technology Goals as presented in ERDA 76–1, Table 1. That Table provides estimated energy impacts in year 2000, but no costs and no intermediate information. Senator Jackson's letter called for both annual costs and annual energy impacts from now till year 2000, for all the programs. In fact, such impacts were called for in the original legislation, PL 93–577 (Appendixes I and II). A partial text of his letter is reproduced below:

> . . . At our recent hearings, several themes surfaced that are directly related to the basic requirement for justification of the elements of the plan. Based on these hearings, it is the Committee's feeling that there is a serious need for more specificity in the plan through targets and costs for the various plan elements. Any plan requires some quantitative measure of success, that is, clearly defined targets that allow others to judge the effectiveness of the actions taken to achieve the planned goals. A sound plan also needs a clear statement of the costs associated with the various plan elements, both to allow evaluation of the cost effectivnesss of the targets, and to allow monitoring of the costs throughout the plan.
>
> . . . The Committee feels that such targets and costs are essential in its evaluation of ERDA's plan and requests that you assemble this information and forward it to us . . .

The full text of this letter and ERDA's response is included in this report as Appendix III. The essential information in the ERDA response has been abstracted and superposed on a copy of Table I from ERDA 76–1, which contains the ERDA Energy Technology Goals.

While a year-by-year estimate of costs and benefits was not supplied, a start in this direction was made by ERDA in its response. This table is shown below:

TABLE 1.—TECHNOLOGIES NOW AVAILABLE FOR PURSUING MAJOR ENERGY TECHNOLOGY GOALS

| Technology | Projected costs (partial or total) | | Present estimate | | Original estimate | |
|---|---|---|---|---|---|---|
| | Amount (in millions of dollars) | Through year | Impact in 1985 in quads | Impact in year 2000 in quads | Impact in 1985 in quads | Impact in year 2000 in quads |
| Goal I: Expand the domestic supply of economically recoverable energy producing raw materials: | | | | | | |
| Oil and gas—enhanced recovery | 250–600 | 1982 | 0.4–2 | 3–12 | 5.4 | 13.6 |
| Oil shale | 100–700 | 1982 | 0–.4 | 1–5 | .9 | 7.3 |
| Geothermal | 650–1, 100 | 2000 | .1–.3 | 1–5 | .7–1.4 | 3.1–5.6 |
| Goal II: Increase the use of essentially inexhaustible domestic energy resources: | | | | | | |
| Solar electric | 800–3, 500 | 1986 | 0–.1 | 2 | .1–4 | |
| Breeder reactors | 9, 000–10, 000 | 1990 | 0 | 2 | 0 | 3.1 |
| Fusion | 14, 000–21, 000 | 2000 | 0 | 0 | 0 | 0 |
| Goal III: Efficiently transform fuel resources into more desirable forms: | | | | | | |
| Coal—direct utilization utility/industry | 800–1, 800 | 1982 | 12–13 | 23–25 | 15.4 | 24.5 |
| Waste materials to energy | 50–200 | 1985 | | | 1.2 | 4.9 |
| Gaseous and liquid fuels from coal | 1, 500–3, 500 | 1982 | 1 | 1–9 | 1.4 | 14.0 |
| Fuels from Biomass | 300–1, 800 | 1990 | .1 | 2 | 0 | 1.4 |
| Goal IV: Increase the efficiency and reliability of the processes used in the energy conversion and delivery systems: | | | | | | |
| Nuclear converter reactors | 4, 000–6, 000 | 2000 | 4.5 | 13–17 | 8.8 | 28.0 |
| Electric conversion efficiency | 300–1, 400 | 2000 | 0 | .4 | 0 | 2.6 |
| Energy storage | 500–1, 000 | 2000 | | | | |
| Electric power transmission and distribution | 200–650 | 2000 | 0 | 1.4 | 0 | 1.4 |
| Goal V: Transform consumption patterns to improve energy utilization: | | | | | | |
| Solar heat and cooling | 200–700 | 1985 | 0.1 | 1–6 | .4 | 5.9 |
| Waste heat utilization | 50–60 | 1982 | ? | ? | .7 | 4.9 |
| Electric transport | 200–300 | 2000 | 0–.1 | 0–.6 | .1 | 1.3 |
| Hydrogen in energy systems | | | 0 | 0 | 0 | 0 |
| Goal VI: Increase end-use efficiency: | | | | | | |
| Transportation efficiency | 300–1, 800 | 2000 | 2.3 | 5–8 | 4.9 | 9.0 |
| Industrial energy efficiency | 150–200 | 1985 | 2.3 | 3–5 | 2.8 | 8.0 |
| Conservation in buildings and consumer products | 200–700 | 1985 | 1–2 | 3–6 | 3.5 | 7.1 |

This letter and response were discussed in some depth in the final hearing. The Committee specifically pointed out that a number of new facts were provided by the above table, for example:

> The estimated impact in 1985 of conservation in Buildings and consumer products had been reduced from 3.5 in the original plan to 1–2 quads now, in spite of the highest priority accorded conservation, and newly authorized programs such as the Energy Extension Service.
>
> The cost of the breeder reactor program from now until 1990 was estimated at $10 billion with no energy benefit by 1985, as contrasted to other less expensive and more productive options.

The Committee indicated the desirability of having such cost and benefit estimates for the various programs in future national energy plans.

*Recommendation.*—ERDA's subsequent energy plans should estimate both the costs and benefits of the various energy technologies being pursued, as called for in section 15b of Public Law 93–577. It would be desirable to have these estimates on an annual basis over the life of the plan, although some larger time period may be suitable. These estimates are essential in allowing Congress to judge the funding rationale for various programs at annual authorizations. Estimates of costs and benefits should also include an analysis of consequences which might be expected to occur if ERDA funding for the energy technology is eliminated or significantly changed.

### D. ENVIRONMENTAL, SOCIAL AND ECONOMIC IMPACTS

Section 15(b) of Public Law 93–577 calls for estimates of the environmental, social, and economic impacts for the proposed technology programs. Congress and the public needs to be aware of the best estimates of the environmental problems, the social disruptions, and the economic impacts that may be associated with alternative energy sources, in order to choose the best policy for energy development. This theme was stressed by several witnesses, and reaffirmed by the Committee during the hearings.

While information on all of these impacts is important for the national plan, the costs of energy with and without the ERDA effort was specifically requested from ERDA based on testimony at one of the hearings. A partial text of the requesting letter from Senator Jackson to Dr. Seamans is shown below:

> . . . At the July 29th set of hearings on the ERDA National energy plan, Dr. Barry Commoner presented testimony regarding the economic impact of ERDA's plan. His basic thesis was that the present plan will lead to increases in energy cost that will have severe impacts throughout our economy. He recommends different emphases to avoid this situation and his advice will certainly be given dur consideration.
>
> . . . However, before the Committee can evaluate his advice in depth, it would be necessary for estimates to be made on the future cost of energy under different conditions.

> As a minimum, it would be desirable for the Committee to have ERDA's forecast of energy prices (coal, oil, nuclear, etc.) for the balance of the century with no R & D effort and with the effort envisioned in ERDA's National Energy Plan.

The full text of the letter and ERDA's response is included as Appendix IV of this report. ERDA's response noted the impossibility of exact prediction of future energy prices, but the results of five scenarios for future energy prices in year 2000 were included. These secenarios are (1) status quo, *i.e.*, no ERDA R, D & D program; (2) improved efficiency in energy usage; (3) development of synthetic fuels; (4) emphasis on electrification; and, (5) a combination of scenarios (2) through (4). The resulting energy prices are shown in the table below, and ERDA's response suggests that intensive electrification would result in energy costs nearly as great as with no energy R, D & D program, while achievement of improved efficiences could lower energy costs more than any other single scenario. The letter also notes that solar electric technologies will result in energy costs considerably above that using other electrical energy approaches.

It can be seen that the present ERDA response is only a starting point in answering the question raised by Senator Jackson's letter, since it only provides energy costs at one point in time in the future, rather than starting with today's values and predicting their estimated values at various future points with and without the government financed R, D & D programs. A more detailed response would be necessary for proper consideration of the impact of the various scenarios.

FUTURE ENERGY COSTS

| Scenario | Total cost in billions of dollars in year 2000 | Average cost in millions of dollars per Btu of resources used in year 2000 |
|---|---|---|
| No ERDA R.D. & D | 498.9 | 3.02 |
| Improved efficiencies | 325.6 | 2.74 |
| Synthetic fuels | 460.5 | 2.78 |
| Intensive electrification | 469.5 | 2.98 |
| Combination of techniques | 328.7 | 2.46 |

*Recommendation.*—ERDA is asked to devote more efforts to following the mandate of the enabling legislation by providing social, economic, and environmental impacts for the various programs it is supporting. This effort should be an integral part of whatever rationale ERDA develops to justify the programs it is pursuing, and it should appear as part of the national energy plan.

TIMING OF THE PLAN

Public Law 93-577 calls for ERDA to present its annual plan update *concurrent* with the annual budget request. Past practice has resulted in the plan not being available until after the Committee has examined and made final judgments about the annual ERDA authorization. This situation clearly hampers the best resource allocation decisions by the Committee.

*Recommendation.*—ERDA's national energy plan should be delivered to Congress concurrent with the annual budget request, as called for in the ERDA enabling legislation.

# APPENDIXES

## Appendix I

Section 6 of Public Law 93-577
(Comprehensive Planning and Programing)

COMPREHENSIVE PLANNING AND PROGRAMING

SEC. 6. (a) Pursuant to the authority and directions of this Act and the Energy Reorganization Act of 1974 (Public Law 93–438), the Administrator shall transmit to the Congress, on or before June 30, 1975, a comprehensive plan for energy research, development, and demonstration. This plan shall be appropriately revised annually as provided in section 15(a). Such plan shall be designed to achieve—

(1) solutions to immediate and short-term (to the early 1980's) energy supply system and associated environmental problems;

(2) solutions to middle-term (the early 1980's to 2000) energy supply system and associated environmental problems; and

(3) solutions to long-term (beyond 2000) energy supply system and associated environmental problems.

(b)(1) Based on the comprehensive energy research, development, and demonstration plan developed under subsection (a), the Administrator shall develop and transmit to the Congress, on or before June 30, 1975, a comprehensive nonnuclear energy research, development, and demonstration program to implement the nonnuclear research, development, and demonstration aspects of the comprehensive plan.

(2) This program shall be designed to achieve solutions to the energy supply and associated environmental problems in the immediate and short-term (to the early 1980's), middle-term (the early 1980's to 2000), and long-term (beyond 2000) time intervals. In formulating the nonnuclear aspects of this program, the Administrator shall evaluate the economic, environmental, and technological merits of each aspect of the program.

(3) The Administrator shall assign program elements and activities in specific nonnuclear energy technologies to the short-term middle-term, and long-term time intervals, and shall present full and complete justification for these assignments and the degree of emphasis for each. These program elements and activities shall include, but not be limited to, research, development, and demonstrations designed—

(A) to advance energy conservation technologies, including but not limited to—

(i) productive use of waste, including garbage, sewage, agricultural wastes, and industrial waste heat;

(ii) reuse and recycling of materials and consumer products;

(iii) improvements in automobile design for increased efficiency and lowered emissions, including investigation of the full range of alternatives to the internal combustion engine and systems of efficient public transportation; and

(iv) advanced urban and architectual design to promote efficient energy use in the residential and commercial sectors, improvements in home design and insulation technologies, small thermal storage units and increased efficiency in electrical appliances and lighting fixtures;

(B) to accelerate the commercial demonstration of technologies for producing low-sulfur fuels suitable for boiler use;

(C) to demonstrate improved methods for the generations, storage, and transmission of electrical energy through (i) advances in gas turbine technologies, combined power cycles, the use of low British thermal unit gas and, if practicable magnetohydrodynamics; (ii) storage systems to allow more efficient load following, including the use of inertial energy storage systems; and (iii) improvement in cryogenic transmission methods;

(D) to accelerate the commercial demonstration of technologies for producing substitutes for natural gas, including coal gasification: *Provided*, That the Administrator shall invite and consider proposals from potential participants based upon Federal assistance and participation in the form of a joint Federal-industry corporation, and recommendations pursuant to this clause shall be accompanied by a report on the viability of using this form of Federal assistance or participation;

(E) to accelerate the commercial demonstration of technologies for producing syncrude and liquid petroleum products from coal: *Provided*, That the Administrator shall invite and consider proposals from potential participants based upon Federal assistance and participation through guaranteed prices or purchase of the products, and recommendations pursuant to this clause shall be accompanied by a report on the viability of using this form of Federal assistance or participation;

(F) in accordance with the program authorized by the Geothermal Energy Research, Development, and Demonstration Act of 1974 (Public Law 93–410), to accelerate the commercial demonstration of geothermal energy technologies;

(G) to demonstrate the production of syncrude from oil shale by all promising technologies including in situ technologies;

(H) to demonstrate new and improved methods for the extraction of petroleum resources, including secondary and tertiary recovery of crude oil;

(I) to demonstrate the economics and commercial viability of solar energy for residential and commercial energy supply applications in accordance with the program authorized by the Solar Heating and Cooling Act of 1974 (Public Law 93–409);

(J) to accelerate the commercial demonstration of environmental control systems for energy technologies developed pursuant to this Act;

(K) to investigate the technical and economic feasibility of tidal power for supplying electrical energy;

(L) to commercially demonstrate advanced solar energy technologies in accordance with the Solar Research, Development, and Demonstration Act of 1974 (Public Law 93–473);

(M) to determine the economics and commercial viability of the production of synthetic fuels such as hydrogen and methanol;

(N) to commercially demonstrate the use of fuel cells for central station electric power generation;

(O) to determine the economics and commercial viability of in situ coal gasification;

(P) to improve techniques for the management of existing energy systems by means of quality control; application of systems analysis, communications, and computer techniques; and public information with the objective of improving the reliability and efficiency of energy supplies and encourage the conservation of energy resources; and

(Q) to improve methods for the prevention and cleanup of marine oil spills.

79-744 O - 77 - 4

## Appendix II

Section 15 of Public Law 93–577

(Reports to Congress)

REPORTS TO CONGRESS

SEC. 15. (a) Concurrent with the submission of the President's annual budget to the Congress, the Administrator shall submit to the Congress each year—

(1) a report detailing the activities carried out pursuant to this Act during the preceding fiscal year;

(2) a detailed description of the comprehensive plan for nuclear and nonnuclear energy research, development, and demonstration then in effect under section 6(a); and

(3) a detailed description of the comprehensive nonnuclear research, development, and demonstration program then in effect under section 6(b) including its program elements and activities, setting forth such modifications in the comprehensive plan referred to in clause (2) and the comprehensive program referred to in clause (3) as may be necessary to revise appropriately such plan and program in the light of the activities referred to in clause (1) and any changes in circumstances which may have occurred since the last previous report under this subsection.

(b) The description of the comprehensive nonnuclear research, development, and demonstration program submitted under subsection (a)(2) shall include a statement setting forth—

(1) the anticipated research, development, and application objectives to be achieved by the proposed program;

(2) the economic, environmental, and societal significance which the proposed program may have;

(3) the total estimated cost of individual program items;

(4) the estimated relative financial contributions of the Federal Government and non-Federal participants in the research and development program;

(5) the relationship of the proposed program to any Federal national energy or fuel policies; and

(6) the relationship of any short-term undertakings and expenditures to long-range goals.

(c) The reports required by subsections (a) and (b) of this section will satisfy the reporting requirements of section 307(a) of the Energy Reorganization Act of 1974 (Public Law 93–438) insofar as is concerned activities, goals, priorities, and plans of the Energy Research and Development Administration pertaining to nonnuclear energy.

## Appendix III

## Cost-Benefit Correspondence

August 2, 1976

Dr. Robert Seamans
Administrator
Energy Research and Development
Administration
20 Massachusetts Avenue, N.W.
Washington, D.C. 20510

Dear Dr. Seamans:

As you are aware, the Energy Research and Water Resources Subcommittee of the Senate Committee on Interior and Insular Affairs is reviewing ERDA's National Energy Plan. Such a plan was originally called for in Section 6 of the Non-Nuclear Energy Research and Development Act of 1974, and it was to be designed to achieve solutions to the energy supply problem for the short, middle and long terms with "full and complete justification" of the various elements of the plan.

At our recent hearings, several themes surfaced that are directly related to the basic requirement for justification of the elements of the plan. Based on these hearings, it is the Committee's feeling that there is a serious need for more specificity in the plan through targets and costs for the various plan elements. Any plan requires some quantitative measure of success, that is, clearly defined targets that allow others to judge the effectiveness of the actions taken to achieve the planned goals. A sound plan also needs a clear statement of the costs associated with the various plan elements, both to allow evaluation of the cost effectiveness of the targets, and to allow monitoring of the costs throughout the plan.

While the ERDA national energy plan as stated in ERDA 76-1, "Creating Energy Choices for the Future", is admirable in many ways, it does not have clearly defined,targets and costs associated with the various program elements. The Committee feels that such targets and costs are essential in its evaluation of ERDA's plan, and requests that you assemble this information and forward it to us. Since you will be testifying again late in September, we would appreciate having this information prior to your appearance here for our review.

There are obviously many ways to prepare the requested information and to minimize this uncertainty we will define an approach that we feel will be useful for this first effort. In Volume 76-1; Table I, on page 7 lists technologies now available for pursuing ERDA's major energy technology goals. Each of these technologies, such as oil shale, solar heating and cooling, conservation buildings and consumer products, etc., reflect existing programs in ERDA. The Table also presents the maximum estimated impact of each program in terms of potential substitution for oil in year 2000. For each of these technologies the Committee would like to know ERDA's best estimate for the potential year-by-year oil substitution impact and program cost between now and year 2000. This information is an important part of the "full and complete justification" called for in the original legislation, and would provide Committee members with a much better basis for reviewing ERDA's total national plan.

We appreciate the many difficulties and uncertainties involved in making such target and cost estimates. For example, policy actions beyond ERDA's control, socio-economic difficulties, or other unforeseen factors can drastically effect any projections that go so far into the future. Also, many of the programs may have little or no effect in the near term, and yet require heavy expenditures now due to their long term impact. Finally, it is likely that these estimates will change from year to year as more information becomes available.

While these difficulties are present in any planning effort, they do not absolve ERDA from making the best estimate possible, nor the Congress from beingg fully informed of these estimates and making whatever difficult policy decidions may lie ahead. Theeefore we hope you will give this matter your utmost attention, due to its central relationship to ERDA's basic mission.

Sincerely yours,

Henry M. Jackson
Chairman

HMJ:ccc

UNITED STATES
ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION
WASHINGTON, D.C. 20545

September 28, 1976

Honorable Henry M. Jackson
Chairman
Committee on Interior and Insular Affairs
United States Senate

Dear Mr. Chairman:

Your letter of August 2, 1976, requested that I prepare and forward to you targets for energy impact and the associated RD&D costs for each of the program elements outlined in ERDA 76-1, "Creating Energy Choices for the Future." The information you requested is included in Attachments A and B respectively. However, before you turn to them I want to make several observations.

I agree that there is a need for greater specificity in cost and energy impacts of RD&D programs, but, as your letter recognizes, there are many difficulties in making such estimates and even greater difficulties in using and evaluating the information.

For example, our energy impacts for the years 1985 and 2000 are presented as estimates of the degree of market penetration or market share that each of the technologies may be able to achieve in those years. The estimates are presented as ranges because of the uncertainties inherent in estimating the magnitude of the impact. These impact estimates are subjective and are obtained from an interdisciplinary approach that includes consideration of available computer model forecasts.

To obtain these estimates, many assumptions had to be made for each technology. The assumptions deal with such factors as:

- status of competing technologies
- dates and types of technological innovations
- probability of success
- rate and degree of interaction by industry
- public preferences and attitude
- long-term economic trends, including world oil prices
- relative energy prices
- resource availability
- consumption or demand patterns, etc.

These estimates will change as improved data are obtained and methods of estimation are further developed. Some of our continuing efforts include modeling the Nation's energy system with attention to macro-economic impacts and the use of other analytical tools such as market potential analyses, venture analyses, and cost-benefit analyses. ERDA 77, to be published next February, will contain updated energy RD&D estimates. Since this work is still in progress, we do not yet have complete data or analyses, but what preliminary information we do have is included in Attachment A.

Please note that the energy impact estimates given are not the results of selecting a single set of input assumptions describing the Nation's energy and economic future. Key input assumptions concerning the price of oil, environmental degradation policy, nuclear power restraints, or federal incentives programs for example, can significantly alter the market share achieved by a given technology. The impact estimates presented represent a range of probable impacts which a given technology may achieve in futures generally favorable to the technology. The estimates are therefore not additive since they are derived from different future scenarios.

The RD&D program cost estimates are given in Attachment B. It is important to understand that these estimates assume a high priority for each particular technology over the stated time. Although such an assumption is the best we can do now for planning purposes, it is to be expected that cost estimates for some programs will be reduced in the future as choices are made and priorities are further refined based on more complete data and analysis. Furthermore, these cost estimates generally represent federal activities and do not include efforts by the private sector. The efforts by the private sector are exceedingly important for each technology, and we are now attempting to gather relevant data. This program will be difficult due to the sensitive nature of the information and the general lack of appropriate analytical techniques.

We are still developing the techniques and information necessary to improve our procedures for allocating resources among the many energy R&D options. More work is required before we will have a definitive basis for planning resource requirements with respect to: the appropriate role of the Federal Government; program pace; degree of program risk; and status of competing technologies. In addition, the cost estimates given in Attachment B are not constrained by budgeting or other considerations but represent an optimum schedule for each area. As a result, these cost estimates cannot be aggregated.

It is tempting to simplify the complexities of our program by taking the ratio of projected RD&D costs for a technology to its estimated energy impact and calling it a "cost-benefit" calculation. Unfortunately, this can be quite misleading. For example, the ratio thus obtained does not take into account all of the benefits, such as: the value of producing a particularly valuable (or scarce) fuel form; its contribution to reducing dependence on foreign sources; the pay-off of longer term technologies that will be invaluable in future years but produce few quads in the shorter term, etc.; nor does a calculation consider all of the costs such as efforts by the private sector, environmental or social acceptability, etc.

In summary, I would like to observe that a consideration of the relative RD&D expenditures of our energy technologies requires a very careful cost-benefit analysis. Even with the best of cost-benefit analyses, the results will be constrained by the uncertainties of estimating market shares in futures that cannot be well defined. These uncertainties derive primarily from the forecast sensitivity to factors such as energy policy, government programs, economics of the technology, and market situations. Members of my staff are ready to meet with your staff and discuss the attached estimates, our current efforts, and our future aspirations to refine the energy impact and program cost data.

I trust that these data are responsive to the needs of your Subcommittee and staff.

Sincerely,

Robert C. Seamans, Jr.
Administrator

Enclosures:
A - Energy Impact Estimates
B - Projected Program Costs for Major Technologies

cc: Honorable Paul J. Fannin
United States Senate

ATTACHMENT A

## ENERGY IMPACT ESTIMATES

ERDA is presently implementing a new system to develop a consistent set of energy impact estimates for new technologies. The most comprehensive set which currently exists was prepared in the spring of 1975 for ERDA-48 and appeared again as Table 1 in ERDA 76-1, Volume I.

This attachment discusses each of the numbers presented in this table and indicates our current thinking with respect to possible changes. It is our intent to have a complete set of updated impact estimates available in the near future. Before reviewing the old estimates and presenting our latest views, however, it is necessary to discuss the major problems associated with developing a coherent list and the methodology employed in making these estimates.

The first problem is where in the energy system to measure the quantity of energy saved or supplied. For consistency, measurement of all impacts must be made at the same point in the energy system. The two logical choices are at the point of resource extraction and at the point of end use, see the attached energy flow diagram. The latter point has been chosen as it is considered more important to examine the impacts of a new technology from the perspective of the final consumer since it is his decision with respect to which type of energy he purchases that ultimately drives the system. As a consequence of this convention, supply impacts have been adjusted downward to reflect the losses incurred during cleaning and processing of the fuel and transmission to the point of sale. Consumption impacts have been increased to reflect combustion losses.

To facilitate appropriate comparison and aggregation* of these impacts, it is necessary to express them in units which are consistent. The unit of measurement chosen for this list is a quad, equal to one quadrillion ($10^{15}$) Btu's. This is generally accomplished by converting the quantity of fuel purchased to Btu's on the basis of its theoretical heating value. Conversion from kilowatt hours (kwh), the standard measure for electrical output, to Btu's, however, presents a particular problem. At one extreme the kwh can be measured at its theoretical heating value, 3413 Btu's per kilowatt hour. However, this understates the impact of electricity generating technologies relative to the others as electricity is more valuable in its use than a Btu of oil or gas due to its greater

---

* This list of impact estimates is not additive since the individual estimates are based on futures generally favorable to the particular technology rather than a single future which balances one set of supplies against a set of demands. Secondary impacts are not included such as the energy savings resulting from reduced capital equipment requirements due to conservation.

versatility and application in end uses with higher efficiencies. At the other extreme one can convert a kwh in terms of the fuel required to produce it. The average heat rate of a typical fossil fuel electric power plant is approximately 10,000 Btu's per kwh. More efficient technologies have a lower heat rate while some new sources such as solar and geothermal power plants will have higher rates. A middle ground conversion factor is provided based on the amount of oil and gas which would be replaced by electricity in those end uses where they compete - space heating, water heating, industrial heat, etc. Such a conversion factor can be calculated for each new scenario or case used in estimating impacts. The resulting value is in the range of 5500-7000 Btu's per kwh hour.

The current estimates presented here are in most cases less than or equal to those contained in ERDA-48 and ERDA 76-1. These changes have come about not as a result of changing the methodology for estimating them but rather due to refinements of that methodology and the availability of additional information. The initial ones were from the six hand-generated Reference Energy System scenarios presented in ERDA-48. The current estimates are primarily the inputs to computer simulations of new Reference Energy System scenarios. These scenarios represent possible energy futures in 1985 and 2000 considering economic growth and energy consumption patterns under various constraints. The upper bound for the impact of a technology is computed considering its potential market, technical characteristics, possible institutional constraints, and other economic factors independent of competition from other technologies for the same markets. Further refinement involving the results of additional scenario calculations and environmental considerations will be incorporated in the system for the development of a complete set of estimates. At a minimum, annual revisions of the impact estimates are anticipated to reflect further model refinements and our expanded knowledge of the technologies, market and constraints.

## Symbols

Symbols used in this attachment are:

MMBPD - Million Barrels of Oil Per Day
MWe - Megawatt Electric
GWe - Gigawatt Electric
KWH - Kilowatt Hour

GOAL I: EXPAND THE DOMESTIC SUPPLY OF ECONOMICALLY RECOVERABLE ENERGY PRODUCING RAW MATERIALS

| | | 1985* | 2000* |
|---|---|---|---|
| Oil and Gas - Enhanced Recovery: | ERDA-48 | 5.4 | 13.6 |

These estimates are for incremental increases in oil production and were used in all of the scenarios but Scenario 0. They were based on gross resource assumptions as shown in Figures 2-1 and 2-2 of ERDA-48. The 1985 estimates reflected very preliminary program targets and the 2000 estimates an extrapolation constrained by resources.

| | | | |
|---|---|---|---|
| Current Estimate: | | 0.4-2 | 3-12 |

The estimate reflects more realistic RD&D program goals for 1985 and 2000. It also reflects partial deregulation of domestic oil and natural gas prices and concurrent increases in the price of imported oil.

| | | | |
|---|---|---|---|
| Oil Shale: | ERDA-48 | 0.9 | 7.3 |

The estimates reflected enactment and implementation of the Synthetic Fuels Commercialization Program as envisioned in mid-1975 and growth to a level of 4 MMBPD by 2000. The high rates were used in Scenarios II, IV and V.

| | | | |
|---|---|---|---|
| Current Estimate: | | Up to 0.4 | 1-5 |

The current estimates reflect a more realistic market penetration potential. Environmental considerations may require a shift to second and later generation in situ techniques.

| | | | |
|---|---|---|---|
| Geothermal: | ERDA-48 | 0.7-1.4 | 3.1-5.6 |

Two sets of estimates were provided reflecting more or less electric generation depending on whether or not there was a nuclear moratorium. Direct thermal applications were the same in both estimates.

| | | | |
|---|---|---|---|
| Current Estimate: | | 0.1-0.3 | 1-5 |
| (converted to trillions of kwh of electricity) | | (.03-.09) | (0.3-1.5) |

The high estimate reflects 20% compounded annual growth rate from an existing base of 500 MWe. It includes both hydrothermal and geopressured resources. This case also assumes rapid resolution of associated environmental problems. This estimate could be substantially reduced by environmental and other delays. Only hydrothermal resources contribute to the low impact. Impacts are geographically limited to the Pacific and Southwestern states.

* All impacts estimates are for the particular year indicated only.

GOAL II: INCREASE THE USE OF ESSENTIALLY INEXHAUSTIBLE DOMESTIC ENERGY RESOURCES

| | | 1985 | 2000 |
|---|---|---|---|
| Solar Electric: | ERDA-48 | 0.1-4 | 2.1-4.2 |

These estimates reflect the combination of wind, photovoltaic, solar thermal and ocean thermal power plants. As in the case of geothermal, two cases were provided, one reflecting a nuclear moratorium and the other the best that might be done in competition with nuclear. No more explicit considerations of cost were included in the analyses.

| | | | |
|---|---|---|---|
| Current Estimate: | Up to | 0.1 | Up to 2 |
| (converted to trillions of kwh of electricity) | | (.03) | (0.6) |

The solar electric program consists of the following components:

Wind - The estimate assumes installation of 21,000 wind generators in wind parks of 100 units by 2000. Growth starts in the mid-80's and continues at 15% compounded per year.

Photovoltaic - In this case a 1980 commercial introduction is assumed. A 1% penetration of the lighting, miscellaneous and electric drive application markets is assumed in the first year and 5% by the fifth year.

Solar Thermal - An early 1990's introduction is assumed with a growth rate slightly below wind generators.

OTEC - The estimate reflects a 1992 commercial introduction with a conservative growth rate.

| | | | |
|---|---|---|---|
| Breeder Reactors: | ERDA-48 | Negligible | 3.1 |

The estimate is based on commercialization in the early 1990's and rapid growth to 80 GWe installed in 2000.

| | | |
|---|---|---|
| Current Estimate: | 0 | Up to 2 (.6 trillion kwh) |

A 1993 on-line date is assumed for the first plant with market penetration paralleling the LWR experience. This leads to about 54 GWe installed by 2000.

| | | | |
|---|---|---|---|
| Fusion: | ERDA-48 | 0 | 0 |

Commercialization is not expected until after the year 2000. Test and demonstration plants should operate sooner.

Current Estimate: No change from ERDA-48.

GOAL III: EFFICIENTLY TRANSFORM FUEL RESERVES INTO MORE DESIRABLE FORMS

| | | 1985 | 2000 |
|---|---|---|---|
| Coal-Direct Utilization Utility and Industry | ERDA-48 | 15.4 | 24 |

These estimates include coal consumption for heat and power in industrial and utility markets. Direct use of low Btu gas produced on site was included. No attempt was made to distinguish between existing and new technology based on the assumption that RD&D was required to overcome environmental problems such as sulfur oxides control.

| | | | |
|---|---|---|---|
| Current Estimate: | | 12-13 | 23-25 |

This estimate includes all coal consumption for utility and industry markets except low Btu gas. It includes fluidized bed combustion and other advanced, clean, direct combustion technologies for utility and industrial use.

| | | | |
|---|---|---|---|
| Waste Material to Energy | ERDA-48 | 1.2 | 4.9 |

These estimates reflect the direct combustion of solid wastes to replace coal and energy savings resulting from recycling of primary metals.

Current Estimate:

This category has been revised. The energy contributions from conversion of forest and agricultural residues are included in the new impact estimates for fuels from Biomass.

| | | | |
|---|---|---|---|
| Gaseous and Liquid Fuels From Coal | ERDA-48 | 1.4 | 14 |

These estimates include synthetic liquids and high Btu gas from coal resulting from passage and implementation of the Synthetic Fuels Commercialization Program as envisioned in 1975. It is based on 0.7 MMBPD of product in 1985 and 7 MMBPD in 2000. The explicit split between gas and liquid was not analyzed in detail.

| | | | |
|---|---|---|---|
| Current Estimate: | | Up to 1 | 1-9 |

The current estimates include coal liquifaction, high Btu coal gasification and low Btu coal gasification (including in situ) for non utility use. Utility use of low Btu gas in combined cycle systems is included under advanced power systems. Each of the technologies should have commercial scale demonstrations in the early to mid 1980's and grow at rates based on their economic attractiveness in the markets as they exist then. It is generally expected that high Btu gasification will be commercially viable soonest. Both first and second generation plants are included when competitive.

| GOAL III (Continued) | | 1985 | 2000 |
|---|---|---|---|
| Fuels From Biomass | ERDA-48 | Negligible | 1.4 |

These estimates reflect the assumption that the growth of specific crops to produce liquid and gaseous fuels will be relatively modest through the remainder of the century.

| | | | |
|---|---|---|---|
| Current Estimate: | Up to | 0.1 | Up to 2 |

**The technology includes the contribution of synthetic liquids and gases derived from forest and agricultural residues as well as from crops grown expressly for their energy content. The impacts reflect potential difficulties attributable to economic and environmental uncertainties, principally alternative land use questions, and the technical problems of aqua-culture.**

GOAL IV: INCREASE THE EFFICIENCY AND RELIABILITY OF THE PROCESSES USED IN THE ENERGY CONVERSION AND DELIVERY SYSTEMS

| | | 1985 | 2000 |
|---|---|---|---|
| Nuclear Converter Reactors | ERDA-48 | 8.8 | 28 |

These estimates were based on relatively optimistic 1975 assumptions of 185 GWe installed capacity in 1985 and 720 GWe installed capacity in 2000. Both LWR's and HTGR's were included in this category.

| | | | |
|---|---|---|---|
| Current Estimate: | | 4-5 | 13-17 |
| (converted to trillions of kwh of electricity) | | (1.2-1.5) | (3.9-5.0) |

The changes reflect major delays in building of new capacity -- a maximum of 166 GWe in 1985 and 566 GWe in 2000-- as well as a slightly lower assumed capacity factor. The higher impacts include the effects of streamlining licensing requirements and resolution of current concerns involving:

- resource assessment
- enrichment
- recycle
- waste management
- safety and safeguards.

| | | | |
|---|---|---|---|
| Electric Conversion Efficiencies | ERDA-48 | Negligible | 2.6 |

These estimates reflect improvements in the efficiency of generating electricity from coal. The quads are in terms of the coal saved. No tie to explicit new technologies was made.

| | |
|---|---|
| Current Estimates: | 0 up to 4 |

This area now includes the impacts of all the new technologies which convert heat mechanically, electrochemically, and thermodynamically into electricity. Of the various advanced power systems, MHD, fuel cells, and combined cycles (including those using low Btu gas) are expected to be the principal users of coal. Implementation assumptions are consistent with those of the other direct combustion technologies discussed previously. However, a slight lag in the operation of the first commercial scale facilities is assumed due to the greater complexity of the technologies and the response time of the utility users.

GOAL IV (Cont'd)

| | | 1985 | 2000 |
|---|---|---|---|
| Energy Storage | ERDA-48 | -- | -- |

No impacts were provided in ERDA-48 for the reasons discussed below.

Current Estimate:

The technology impacts result from direct energy savings through more efficient energy utilization, recovery and storage of waste energy, and facilitating the implementation of solar and wind sources. Examples include thermal storage for solar heating and cooling, batteries for electric vehicles, and closed loop chemical systems as a more efficient energy transfer and storage technique. As a result, the role of storage is critical to the success of electric transport, solar heating and cooling, and solar electric systems. This fact is reflected in the impact estimates for these related technology areas.

| | | | |
|---|---|---|---|
| Electric Power Transmission and Distribution | ERDA-48 | Negligible | 1.4 |

These estimates are based on widespread implementation of new, lower loss transmission technologies which reduce losses by 25%.

| | | |
|---|---|---|
| Current Estimate: | Negligible | 1.4 |

These estimates reflect only the savings available from reduced electricity transmission and distribution losses which represent a portion of the total energy savings impact of the ERDA research under the Electric Energy Systems subprogram. Methods for estimating the impacts of these additional savings are being evaluated and the results will be incorporated in future impact lists. An additional motivation for this research includes facilitation of the use of more abundant domestically available energy forms and new sources to replace oil and gas.

GOAL V: TRANSFORM CONSUMPTION PATTERNS TO IMPROVE ENERGY UTILIZATION

| | | 1985 | 2000 |
|---|---|---|---|
| Solar Heating and Cooling | ERDA-48 | 0.4 | 5.9 |

These estimates include both solar heating and cooling for building use as well as agricultural and industrial use. They were used in Scenarios I, III, IV and V.

| | | |
|---|---|---|
| Current Estimate: | Up to 1 | 1-6 |

The projection assumes solar conditioning in 10% of the new building starts by 1985 with ten times as many solar installations by 2000. Further increases are attributed to higher rates of market penetration. Economics are assumed to be favorable for solar heating and cooling due to higher competing fuel costs or as a result of various subsidies. Agricultural and process heat applications are included.

| | | | |
|---|---|---|---|
| Waste Heat Utilization | ERDA-48 | 0.7 | 4.9 |

Estimates assume widespread use of waste heat from electric generation for other low grade energy uses.

Current Estimate:

This category is being reviewed. Some savings may be included in conservation items; no new estimate is available.

| | | | |
|---|---|---|---|
| Electric Transport | ERDA-48 | 0.1 | 1 |

Assumes a 1% market penetration for electric automobiles in 1985 and 10% in 2000.

| | | |
|---|---|---|
| Current Estimate: | Up to 0.1 | Up to 0.6 |

Assumes a 2% market penetration for electric automobiles in 1985 and 13% in 2000, and that electric cars average 7,000 miles per year, per vehicle. Differences from ERDA-48 are due to reduced estimates of market size, vehicle efficiencies and mileage traveled per vehicle. The impact is significant in that it represents direct savings of oil assuming the electricity is not generated by oil fired power plants.

| | | | |
|---|---|---|---|
| Hydrogen in Energy Systems | ERDA-48 | 0 | 0 |

A distant technology with widespread commercialization potential not expected before 2000.

| | |
|---|---|
| Current Estimate | No change from ERDA-48 |

GOAL VI: INCREASE END-USE EFFICIENCY

| | | 1985 | 2000 |
|---|---|---|---|
| Transportation Efficiency | ERDA-48 | 4.9 | 9.0 |

Estimates reflect all of the savings anticipated from improved efficiency, lower vehicle weight and new mileage standards resulting in an increase of the fleet average to 28 MPG in 2000

| | | | |
|---|---|---|---|
| Current Estimate | | 2-3 | 5-8 |

Efficiency improvements due to engine and vehicle design RD&D, plus increased load factors in sea, ground and air transportation modes will contribute over half of the total savings estimated. These estimates also assume federally enforced fuel consumption standards for the automobile industry.

| | | | |
|---|---|---|---|
| Industrial Efficiency | ERDA-48 | 2.8 | 8.1 |

Assumes various improvements in process and combustion efficiencies as shown in Table B-2 of ERDA-48.

| | | | |
|---|---|---|---|
| Current Estimate: | | 2-3 | 3-5 |

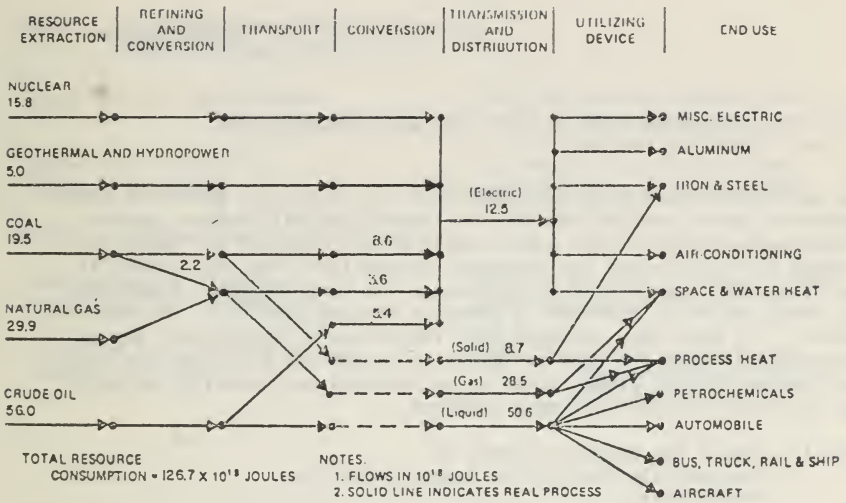
Increased industrial process efficiencies through federally enforced standards ; RD&D; and incentives for energy efficient equipment and process design are assumed.

| | | | |
|---|---|---|---|
| Conversion in Buildings and Consumer Products | ERDA-48 | 3.5 | 7.8 |

Estimates are based on a variety of technical improvements in building shells and equipment performance as shown in Table B-2 of ERDA-48.

| | | | |
|---|---|---|---|
| Current Estimate: | | 1-2 | 3-6 |

The impact estimate is based on stringent thermal efficiency standards as part of the building codes. Improvements in appliance efficiencies will contribute also. Incentives for new construction and retrofit of insulation and improved heating and cooling systems is assumed with mandatory minimum efficiency requirements for these systems.




Reference Energy System (1985)

ATTACHMENT B

PROJECTED PROGRAM COSTS FOR MAJOR TECHNOLOGIES

The total ERDA Program Costs listed below by technology goals are gross estimates based upon the President's Fiscal Year 1977 Budget Request. Dollar projections through a given year (e.g., 1982) do not imply the program ends that year, but represent projections that can be made at this time with some degree of confidence for each program. Generally, the lower estimates represent a moderate program growth for existing efforts. It must also be noted that these cost estimates were derived independently from the quad estimates in Attachment A and are not based on a common source; thus, there is no validity in comparing the quad and the dollars within or among programs.

Goal 1: Expand the Domestic Supply of Economically Recoverable Energy Producing Raw Materials

| | |
|---|---|
| Oil & Gas - Enhanced Recovery | $ 250-600 million through 1982 |
| Oil Shale | $ 100-700 million through 1982 |
| Geothermal | $ 650-1100 million through 2000 |

Goal 2: Increase the Use of Essentially Inexhaustible Domestic Energy Resources

| | |
|---|---|
| Solar Electric | $ 800-3500 million through 1986 |
| Breeder Reactors | $ 9,000-10,000 million to 1990 for LMFBR Program |
| Fusion | |
| Magnetic | $10,000-15,000 million through 2000 |
| Laser | $ 4,000- 6.000 million through 1995 |

Goal 3: Efficiently Transform Fuel Resources Into More Desirable Forms

| | |
|---|---|
| Coal - Direct Utilization | $ 800-1,800 million through 1982 |
| Waste Materials Technology | $ 50-200 million through 1985 |
| Gaseous & Liquid Fuels from Coal | $ 1,500-3,500 million through 1982 |
| Fuels from Biomass | $ 300-1,800 million through 1990 |

Coal 4: Increase the Efficiency and Reliability of Processes Used in Energy Conversion

| | |
|---|---|
| Nuclear Converter Reactors | $ 4,000-6,500 million through 2000 |
| Electric Conversion Efficiency | $ 300-1,400 million through 2000 |
| Electric Storage | $ 500-1,000 million through 2000 |
| Electric Power Trans & Dist | $ 200- 650 million through 2000 |

| | |
|---|---|
| Goal 5: Transform Consumption Patterns to Improve Energy Utilization | |
| Solar Heating and Cooling | $200-700 million through 1985 (Includes Agricultural and Industrial Process Heat) |
| Waste Heat Utilization | $ 50-60 million through 1982 |
| Electric Transport | $200-300 million through 2000 +165 million |
| Goal 6: Increase End-Use Efficiency | |
| Transportation Efficiency | $300-1,800 million through 2000 |
| Industrial Energy Efficiency | $150-200 million through 1985 |
| Conservation in Buildings and Consumer Products | $250-700 million through 1985 (Includes Energy Extension Service) |

## Appendix IV

## Economic Impact Correspondence

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United States Senate
COMMITTEE ON
INTERIOR AND INSULAR AFFAIRS
WASHINGTON, D.C. 20510

August 23, 1976

Dr. Robert C. Seamans, Jr.
Administrator
Energy Research and
Development Administration
20 Massachusetts Avenue, Northwest
Washington, D. C. 20545

Dear Dr. Seamans:

At the July 29th set of hearings on the ERDA National energy plan, Dr. Barry Commoner presented testimony regarding the economic impact of ERDA's plan. His basic thesis was that the present plan will lead to increases in energy cost that will have severe impacts throughout our economy. He recommends different emphases to avoid this situation and his advice will certainly be given due consideration.

However, before the Committee can evaluate his advice in depth, it would be necessary for estimates to be made on the future cost of energy under different conditions. This estimation would fall under the general requirement of P.L. 93-577 as noted below:

> The description of the comprehensive non-nuclear research, development, and demonstration program . . . shall include a statement setting forth . . . the economic, environmental, and societal significance which the proposed program may have . . . (Sec. 15(b)).

As a minimum, it would be desirable for the Committee to have ERDA's forecast of energy prices (coal, oil, nuclear, etc.) for the balance of the century with no R & D effort and with the effort envisioned in ERDA's National Energy Plan. This information should be prepared for mid-September, prior to your follow-up testimony.

After discussion of this area at the next set of hearings, the Committee can determine the best approach for future National Energy Plans.

Sincerely yours,

Henry M. Jackson
Chairman

HMJ:cck

UNITED STATES
ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION
WASHINGTON, D.C. 20545

SEP 2 9 1976

Honorable Henry M. Jackson, Chairman
Committee on Interior and Insular
Affairs
United States Senate

Dear Mr. Chairman:

In response to your letter of August 23, 1976, my staff has prepared a detailed response that I have attached. I hope that this reply is responsive to your question. I will be happy to answer any further questions that you may have.

Sincerely,

Robert C. Seamans, Jr.
Administrator

Enclosure:
As stated

UNITED STATES
ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION
WASHINGTON, D.C. 20545

September 29, 1976

MEMORANDUM

TO: Administrator

FROM: Assistant Administrator for Planning, Analysis, and Evaluation

SUBJECT: Senator Jackson Letter of August 23, 1976

In Senator Jackson's letter of August 23, 1976, he inquired about future costs of energy and about the potential impact of RD&D on cost trends. Appropriately, he highlighted the central importance of assumptions concerning energy costs in comprehensive energy planning. The law he referenced requires such considerations and ERDA-48, the first National Energy RD&D Plan, examined the future economics of energy development in its supporting analysis.

As we indicated in ERDA-48, there is no way - given our free society and the great uncertainties surrounding such critical planning factors as extent of fuel reserves, R&D breakthroughs, and foreign political decisions - that one can predict or specify the configuration of future United States energy systems. In the absence of such a specification, it is not possible to project energy prices with and without R&D.

It is possible, however, to make certain consistent assumptions about energy technologies in a range of potential futures and thereby gain a planning appreciation for the impact R&D could be expected to have. While such analysis does not yield absolute answers regarding prices, it does emphasize the relative importance of various approaches.

Thus, in the ERDA-48 analysis, we examined five different energy futures - the status quo, three featuring different technological emphasis - i.e., improved efficiencies, heavy dependence on synthetic fuels, rapid electrification and a combination of technology scenarios. For each of these futures the relative economic consequences were presented. I summarize in Table I below two important measures for the year 2000 listed in Appendix B of that report for each of these futures.

Table I
Economic Parameters in Five Energy Futures

| Future | Total Cost in Billions of Dollars in 2000 | Average Cost in Dollars Per Million Btu of Resources Used in 2000 |
|---|---|---|
| Status Quo | 498.9 | 3.02 |
| Improved Efficiencies | 325.6 | 2.74 |
| Synthetics from Coal and Shale | 460.5 | 2.78 |
| Intensive Electrification | 469.5 | 2.98 |
| Combination of Technologies | 328.7 | 2.46 |

As can be seen from these results, any one of the four futures involving wide development of new technologies is projected to have lower total costs as well as lower unit costs than a status quo future that would be dependent on currently available technologies. However, the combination of technologies approach is markedly superior to the others and would also result in maximum reduction of requirements for imported fuel.

I would like to reiterate that too much emphasis should not be placed on the absolute numbers. These continue to change as we refine our analysis. The modeling of the nation's entire energy system is complex and our capability is still evolving.

For example, since ERDA-48 two additional sets of related analysis have been undertaken and can shed light on your question. The first deals with assumptions (not projections) regarding future evolution of fuel prices and assesses potential impact of R&D on such prices. The following Table II indicates price data now being utilized in connection with operation of the analytic models at Brookhaven National Laboratory.

Table II
Real Prices of Energy Resources
(In 1975 dollars per million Btu)

| | With RD&D and Conservation | | | Without Major RD&D Efforts | | |
|---|---|---|---|---|---|---|
| | 1985 | 1990 | 2000 | 1985 | 1990 | 2000 |
| Crude Oil | 2.24 | 2.41 | 3.08 | 2.76 | 3.05 | 4.10 |
| Natural Gas* | 1.93 | 2.13 | 2.73 | 1.93 | 2.24 | 3.32 |
| Coal** | 0.61 | 0.66 | 0.81 | 0.61 | 0.67 | 0.86 |
| Nuclear Fuel*** | 0.65 | 0.70 | 0.81 | 0.72 | 0.78 | 0.91 |

---

* Assuming some continued regulation.

** Costs are mine-mouth before preparation and cleaning; the costs of coal delivered to industry and utilities are estimated at 13 to 32 cents per million Btu higher than shown.

*** Includes total fuel costs of ore, milling, conversion, enrichment, fabrication, transportation, reprocessing and waste disposal.

Direct impacts of RD&D efforts on resource costs are less important than the indirect effects. The direct impacts are through improved recovery techniques for oil and gas, through improvements in the nuclear fuel cycle, etc. The indirect effects of RD&D and conservation alter basic requirements and, therefore, restrain the upward price pressure on these depletable fuels.

In addition to the future cost estimates of the energy resources, we have estimated the capital requirements and the broader effects of alternative energy policies on the functioning of the economy. Analyses performed in conjunction with the preparation of ERDA 76-1 calculated effects on the economy under a policy with no Government-sponsored R&D (Policy A2) as compared with those where energy RD&D plans were fully carried out (Policy A1). The analysis indicated that Policy A2, without the RD&D effort, resulted in a loss of income over time (1980 to 2010) that would greatly exceed the R&D costs necessary to prevent it. The present value (in 1975 dollars calculated at a 10 percent discount rate) of the additional loss of income over time was some $178 billion under Case A2 relative to Case A1. These results do not directly answer the questions posed in your letter, but they are germane to the general issue of R&D planning and energy costs.

ERDA is now in the process of undertaking a major updating of the analysis of potential energy futures to support the next edition of the National Energy RD&D Plan due early in 1977. These scenarios will show in more detail the relative economic and environmental consequences of different technological approaches.

Other analysis underway at ERDA shows that as much of the economic benefit from energy RD&D is in the area of improving energy conversion efficiency and efficiency of end-use devices as is in the area of minimizing fuel costs. It is the energy cost to the end-user for a given output that will determine the impact on real GNP.

Much of ERDA's and the nation's R&D is directed toward developing technologies that will minimize such an increase in energy cost to the end-user, thus ameliorating the effect of escalation of basic fuel prices. This R&D target is most evident in electricity generation. More than 25 percent of all energy in the United States is currently consumed in the process of generating electricity. A number of ERDA projections show this fraction increasing to 50 percent in the next century.

Thus, a key consideration in evaluating many R&D programs is concerned with their potential impact on the nation's total electrical bill for a given level of electrical generation. Recent analyses compare the bus bar costs of electricity from base-loaded conventional coal and nuclear

plants with the costs from new technologies that either are more efficient or employ alternative fuels. The costs of generation from conventional coal and LWR plants increase over time in response to escalating fuel costs.

The introduction of the breeder reactor, however, is projected to arrest the increase in nuclear-generated electricity bus bar costs. In addition, the advanced (more efficient) fossil technologies are also seen to produce lower bus bar costs than does the conventional coal technology.

This preliminary analysis, which is currently being refined within ERDA, suggests that the impact of such new technologies on reducing the nation's electricity bill can be dramatic. Considering a case of high growth in electric demand (5 to 6 percent annually for the remainder of the century and 3 percent beyond), the analysis showed that the present value (discounted at 10 percent in 1975 dollars) of the cost of electricity produced from all plants installed between 1985 and 2020 would be $332 billion for existing technologies and only $288 billion for new plus existing technologies for the same level of demand. Thus, the value in today's dollars of the R&D impact would be $44 billion in base load electrical generation. R&D would thereby virtually arrest the real cost escalation of the average United States electrical power generated over the next 50 years while coal and uranium prices are projected to increase at 1.5 to 2 percent annually.

We note that such savings result from developing a number of new technologies. The significant uncertainty existing for achieving the economic and performance goals of any one of them is diminished by pursuing several competing alternatives. Nonetheless, the nuclear-breeder option now seems to hold greatest economic promise, although more work will be required to make the breeder environmentally acceptable. The advanced coal technologies are also important. Solar electric, however, seems to face considerable disadvantages vis-a-vis other technologies especially for base load generation. Even using optimistic R&D targets, base load solar electric costs would be far higher. Solar electric comes closer to being competitive for intermediate load applications because less storage is needed, but it still would be at the top end of the other technologies' competitive band and then only for this limited fraction of total domestic electricity generated. One could use the same cost data for other sources to estimate just how much one could afford to pay for a solar generating capacity to break even with other options. Preliminary calculations suggest that this would be in the range of $575 to $900 for a kilowatt of system capacity capable of supplying this power 70 percent of the time. These compare with the cost range in our calculations of $1450 to $2700.

The most nearly-economic use of solar energy, for heating and cooling homes and commercial buildings, also has hurdles to overcome for widespread public acceptance. In addition to the problem of high initial

costs of systems, homeowners must be convinced that the systems will be reliable and effective and that their maintenance will not be costly or excessively inconvenient. We expect to see these problems overcome, and, in combination, these alternative sources will help us place limits on both the quantity and the cost of energy imports.

In summary, our analyses indicate that energy RD&D efforts will have the effect of lowering the prices which we would otherwise pay for future energy supplies. Certainly, ERDA planning which is geared to the commercialization of new technologies in the private market must be committed to development of the lower cost domestic sources.

If we are not able to accelerate the development of our least costly and most abundant resources, the costs of energy will continue to increase largely at the discretion of the OPEC cartel. Further, as we exert our preferences for cleanliness, convenience, and environmental protection, these costs must also be incorporated in the consumers' bill for energy. However, we can hope and expect that scientific and technological progress will give us more efficient production and use of energy, new and better products, and eventually lower costs. Herein lies our best hope for eventual control of our own destiny on energy supply and costs.

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